3.0 Dynamic Planning and Execution Control

3.1 Planning and Simulation

Dynamic Planning and Execution Control exploits the information derived through Global Awareness. It is not possible to increase the tempo of operations without increasing the tempo of planning.[12] Planning time should be reduced from days to hours or even minutes. Joint planning will be essential. Reduction of planning time also reduces the time available for review and checking of plans, and the burden of verifying accuracy and effectiveness must shift to automatic systems. Verification of plans will be done by the continuous simulations of the plans using current information about all forces. Consistency checks should be part of all planning and command systems. Displays and planning tools will permit commanders to compare simulations and plans, and to change both easily and consistently. People and databases involved in the Planning and Control process may be separated by thousands of miles. The system will support collaboration through virtual meeting facilities.

3.2 Execution Control

We refer to Execution Control rather than Battle Management as a way of emphasizing that planning and control systems should integrate Mobility and Attack planning in both war and peace. Mobility resources are at least as limited as combat resources,[13] and supply and use of supplies must be coordinated at the same rate as combat operations. Resources used to provide Global Awareness must be integrated into the Execution Control system to supply the information needed for planning and execution at the rate needed to support mobility and combat operations. In an integrated force, the tempo of operations can be no faster than the cycle time of the slowest component of the system. It may be necessary to automate the interpretation of voice commands[14] and responses and to provide automatic translation from one language to another.[15] Although automatic translation may appear to be a distant dream, one should realize that many situations use highly stylized language which should be amenable to machine interpretation and translation.

We should not concentrate solely on producing plans and execution orders at the highest possible rate. The planning and simulation facilities should provide long range estimates at all times. For example, the procurement of a replacement part and its shipment to the point of use may require days. A long range estimate of parts requirements should be produced days ahead of a projected use time. Building munition stocks requires time, but overbuilding stocks is an improper use of mobility resources. This does not mean that long-term plans will not change from, even, hour to hour, but estimates should be consistent and reasonably constant. The automatic systems should be aware of “commitment” times after which changes cannot be made. It is apparent that the execution control system will use expert system technologies extensively.

12. Attack Volume
13. Mobility Volume
14. Information Technology Volume
15. Human Systems/Biotechnology Volume

3.3 Processors and Communications

The computer and communication systems which are needed can be defined in a straightforward way.[16] The Air Force should be prepared to procure high speed parallel computing systems to make the Dynamic Planning and Execution Control system work. Parallel computing over networks is well along in development and will be perfected by the commercial world. The Air Force should take advantage of these developments. Distributed satellite systems, partly or wholly commercial, are a natural way to provide affordable connectivity where fiber is nonexistent. We depend more and more on commercial terrestrial communications networks, because they are redundant, reliable, survivable, and cost effective. We seem to insist, however, on developing military satcom systems in spite of their exorbitant cost and limited performance. During the next decade commercial satcom systems will exceed the capacity and reliability, if not the survivability, of the military systems. Commercial systems will have multiple ground stations which connect to the worldwide fiber system. They will eventually use laser crosslinks and downlinks that will dramatically increase redundancy of the systems. It is likely that the commercial systems, or DoD-owned commercial-like systems, can be used for military purposes more reliably than can completely unique military systems. This will be especially true if other nations develop anti-satellite systems. *The Air Force should consider carefully before investing further in dedicated military satcom systems.*

Digital communications to and from aircraft will be an important aspect of future warfighting. Links of interest include those for one-way broadcast and two-way command and control. For one-way broadcast, adoption of civilian satellite technology is an interim solution which will enable cheap one-way reception of information on a theater-wide basis. Such a wide-area broadcast service would permit all aircraft to receive critical warning messages, weather, and real time surveillance regardless of their location in the theater.

Two-way links for high performance aircraft, whether to satellites, URAVs, or large aircraft, continue to present a challenge. Current systems (low cost modems and higher cost JTIDS) already permit digital links to fighters. Wide area networks can be established through use of gateways on URAVs or large aircraft (such as the Joint STARS or AWACS). Figure II-3 shows the line of sight range between a relay transmitter and a fighter for various altitudes. A URAV at 60,000 feet can transmit line of sight to a fighter at 20,000 feet over a range of more than 400 nm. We recommend that technologies appropriate for direct satellite links to fighters be explored, but the Air Force should continuously evaluate the cost and utility of direct satellite links compared to links through aircraft.

Direct Satellite link to large aircraft and to URAVs is a much simpler and less expensive option. Certainly direct satellite links should be provided to all airlifters, AWACS, Joint STARS, URAVs and tankers. Commercial carriers will probably suffice for the airlifter links and, perhaps, for the tanker links.

16. Information Applications Volume

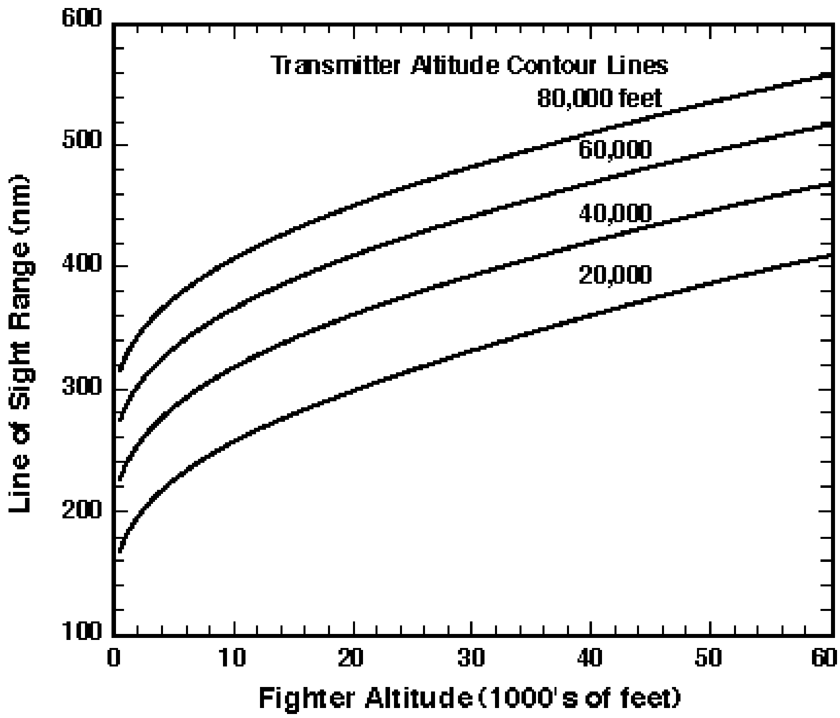

Figure II-3

3.4 User and Developer Interactions

The interaction of users with all systems must be flexible, secure, and situation dependent. Intelligent Agents[17] can be developed to support the interaction. Flexible connectivity can be achieved with commercial operating systems, network protocols, and programming languages. Some argue that only unique military operating systems and government standardization of equipment and protocols can guarantee security. Exactly the opposite is likely to be the case. Creation of a single unique universe increases the probability of a single point failure which can destroy the entire system. The folly of that logic was recognized millions of years ago in biological evolution, because the absence of biological diversity in a species makes the entire species susceptible to a single virus. The Air Force must beware the natural human tendency toward absolute standardization.

It will be necessary to develop security and priority systems which overlay or integrate into commercial systems such as UNIX, the Internet, and C++. These additions should be constructed such that commercial software development tools can be used. The Air Force should not be in the software tool business. Nor should the Air Force be in the computer language and compiler development business. A capability for the use of Ada should be maintained for special cases where it is appropriate. In general, however, Ada has become irrelevant in the information world. Other languages are developing much faster. Insistence upon its use increases

17. Information Technology Volume

cost and development time of systems and reduces the availability of commercial software and tools. It is time that the use of arcane languages such as Ada be relegated to situations where nothing else will suffice.

3.5 Caveats

We have suggested what to do, but it is as important to say what not to do. At all cost the Dynamic Planning and Execution Control System must not be planned as a closed, finished product. If it is to utilize rapidly developing technologies it must be open ended. It should be a growing organism which incorporates advances naturally and gradually. *The Air Force must avoid designs which demand permanent adherence to particular hardware, languages, or operating systems.*

An organic, growing system can be planned and built one section at a time. It is now time to get on with it.

4.0 Global Mobility in War and Peace

Mobility can be the limiting factor in operations. Airlift is also in demand during peacetime for humanitarian operations. Humanitarian operations bring special problems to the Air Force, because they may require airlift aircraft and people to enter regions of high danger. It may not be possible to provide external protection for airlifters or external response to attack. The safety of mobility operations will be increased greatly by Global Awareness and by Dynamic Planning and Execution Control. The Air Force airlift system will be integrated into both systems. Today, it is technologically possible to track shipments and aircraft in real time at reasonable cost. New commercial satellite systems, such as Iridium, can be used to enhance that capability at lower cost and higher reliability.

Airlift is the only transportation mode which can respond to a crisis worldwide in days. The capacity of the system planned for the next two decades is less than that required to support existing forces,[18] even with the addition of the Civil Reserve Air Fleet (CRAF). Airlift capacity depends on storage areas, cargo handling equipment, refueling facilities, and airport capacity as well as on aircraft. Reduction in cargo handling equipment, which includes Army supply trucks, increases capacity, because that equipment is frequently delivered by airlift. We need to improve the efficiency of both aircraft and of delivery methods.

We should search for mobility improvements which are not related to increasing the number of carriers. The capacity of the mobility system depends on lift capability and velocity of the carriers. It is unlikely that the speed of ships, trucks, or aircraft will increase significantly during the next three decades for the bulk of delivered cargo. It is possible to increase the size of vehicles by 50, or even 100 percent, but cost per unit mass delivered will not decrease by as much. Therefore, we seek technologies which reduce the time enroute by other methods and which reduce the amount of materiel needed.

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18. Army Science Board 1994 Summer Study - *Capabilities Needed to Counter Current and Evolving Threats*, April 1995

4.1 Future Airlifters

Worldwide coverage will require aircraft that can fly 12,000 miles, deliver cargo, and return without refueling at the terminal point. Air refueling is a logistics intensive operation, and airlifter refueling can be eliminated. Cargo capacity for airlifters of the 21st century should be 150,000 pounds. With improvements in aircraft and delivery methods, the gross takeoff weight will be 1,000,000 pounds.[19]

First the aircraft. Aircraft such as the C-17 or the B777 are impressive airplanes that outperform their predecessors. They are, however, evolutionary improvements over earlier designs. We asked whether there are aircraft technologies that could give much better performance. The answer was -- yes.[20] The technology lever appears to be large improvement in lift to drag (L/D) ratio of a wing coupled to evolutionary improvement in engines. We examined the Wing in Ground Effect (WIG) as a possibility. Improvements of 20 percent appear possible at altitudes of 0.1 times the wingspan, but there are many drawbacks in the WIG system. It operates at altitudes of a few feet and is restricted to over water transport. We then asked whether there are improvements possible to wings operating out of ground effect. Again, the answer was -- yes. It has been observed that high L/D wings have high aspect ratio. For heavy loads, the wings become quite long and they twist. If the twisting effect can be eliminated, the efficiency of the wing can be increased significantly. A possibility which has been investigated is to add a second fuselage.[21] Calculations indicate that a 40 percent increase in aircraft efficiency can be obtained. The drawback of this system is that wider runways and larger parking areas are needed. Ultimately, new materials should add adequate stiffness to a wing without increasing weight.[22] *In general, it appears that wing research could pay off in significantly higher aircraft efficiencies.*

Engines are undergoing noticeable, if evolutionary, improvements, too. Efficiency increases of 20 percent should be realized during the next decade or two.[23] Significant increases in engine efficiency may be possible through applications of modern adaptive control methods to engines. Fast response controls can reduce the operating margin now reserved to provide protection against engine surges. Improvements of 10 percent appear possible. Further improvements of a few percent may be achieved by using magnetic or air bearings rather than mechanical bearings.

4.2 All-Weather Operation

An improvement that could increase delivery rates substantially in many parts of the world is all weather operation. Auto landing (Category III) using differential GPS and the civil Clear Access (C/A) codes has been demonstrated. The GPS autoland system can also guide the aircraft during taxi in zero-zero conditions (Category IIIc). A wide area differential system, which does not require nearby ground stations has been proposed and demonstrated through the Joint Direct Attack Munition (JDAM) program. Accuracy of 30 cm has been demonstrated. This capability will enable autoland and "blind" taxi anywhere in the world without the addition of equipment on the ground. Installing this capability in airlifters should certainly be a high

19. Mobility Volume
20. Aircraft and Propulsion Volume
21. Mobility Volume
22. Materials Volume
23. Aircraft and Propulsion Volume

priority. Commercial equipment can be used extensively to construct the wide area differential system. Jamming resistance is not improved by the differential system. Its primary advantage is that it can be done now. *It should be done immediately.*

4.3 Point-of-Use Delivery

Next -- delivery methods. An item shipped by military airlift from one point to another will usually spend more time on the ground than in the air during the shipping process. Technology can help to reduce the ground time by providing planning and scheduling of delivery and distribution as mentioned earlier. Efficient planning coupled with real time simulation can help one make the most efficient use of facilities and equipment. It cannot, however, compensate completely for too few cargo handling devices, too little ramp space at receiving airports, diversions because of weather, or damage resulting from enemy attack. If we attempt to deliver to austere runways near a combat area, we place airlifters in danger. Even in peacetime, such as now in Bosnia, delivery is sometimes canceled because of dangerous conditions during landing and takeoff. Bosnia is also an example of a theater where point-of-delivery and point-of-use are separated by hostile territory.

The technologies needed for evolutionary improvements which will enhance capacity are clear. For example, in addition to the planning and execution improvements noted above they include improvements in onboard and offboard handling equipment. We sought ideas that could provide more substantial improvements in delivery rate. The one we have chosen to describe in detail is “point-of-use delivery”. The purpose of point-of-use delivery is to reverse the ratio of cargo ground time to cargo air time. Approach and landing delays will be eliminated. All weather operation will be possible. If cargo can be delivered directly to the user, airport bottlenecks will be eliminated. Secondary benefits will further increase delivery rate. Many of the K-loaders that unload the aircraft will not be needed. Many of the trucks that carry cargo from airport to user will not be needed. The warehouses that store cargo waiting for user pickup will not be needed. Some airports will not be needed. The amount of cargo handling equipment delivered by airlift will be reduced, and the space can be used for cargo. Land transport through enemy territory will be avoided. Cargo density on the ground will, of necessity, be lower than in storage areas, but average delivery density can be higher than on an airport.

If point-of-use delivery can become routine, the effect on Army operations will be profound. This is a truly revolutionary capability. It will be impossible for an Army unit to outrun its supply train. Mobility and maneuver flexibility will be that of the fighting unit rather than that of the supply unit. Supplies will be delivered by large airlifters rather than by truck or helicopter. Possibilities for enhancing maneuver effectiveness are nearly endless. Point-of-use delivery is more than precision airdrop, although it includes precision airdrop. The problems:

- Deliver cargo without landing the aircraft to an accuracy of 10-20 meters from altitudes up to at least 20,000 feet.
- Load aircraft with cargo and drop equipment at the same efficiency as for land delivery.
- Extract cargo in random order.
- Recover and reuse drop equipment unless cost per drop unit is negligible.

At present airdrop is an emergency procedure. Accuracy is poor. Two methods have addressed the problem of improving accuracy. One is to measure wind profile with a LIDAR[24] or a GPS dropsonde and to compute a release point (CARP) based on the wind. The accuracy of this method is limited to 100 meters by parachute reproducibility and measurement accuracy. The second method uses a large, steerable parafoil with GPS based guidance. Both the parafoil and the control system are expensive, and the cargo lands with high forward velocity. A combination of the methods where the parafoil is replaced with a much lower cost system may be effective and affordable. Standard, non-steerable parachutes exhibit forward motion at a few knots. If wind measurements can be made, the forward or "drive" velocity will be adequate to compensate for wind measurement errors. The system can be steered by a GPS controlled steering system on the load. Load mounted steering will permit the use of balanced aerodynamic forces, or trim tabs, and the guidance power will be greatly reduced. A "de-reefing" system deployed at an altitude of a few feet will effect a soft landing with acceleration comparable to forklift handling. The cost of the entire system should be a factor of ten cheaper than currently proposed precision systems. Recovery of equipment can be done by air pickup, an area in which we have much experience. Precision release is an integral part of an airdrop system, but little work has been done in this area. Immediate improvement can be made over the archaic system now used. *In the future, the problem of airdrop should be treated as seriously as the problem of bomb drop*. For example, airlifters equipped with belly doors could deploy cargo randomly, and release precision could be much higher than for deployment through rear doors. *Future airlifters should be designed for point-of-use delivery.* Existing airlift aircraft have all been designed for air-land delivery. An airlifter designed for point-of-use delivery will be quite different.

The question of how to deliver personnel should not be ignored, but we admit to having no completely new ideas. Airdrop of personnel in individual parachutes is inefficient and dangerous. The density of troops on the ground is low, and there is an extended period of vulnerability after landing. There is no reason that personnel could not be dropped in containers using the same equipment as described above for cargo if accuracy and safety can be guaranteed. Personnel drop vehicles could be armored with lightweight armor of the type now used on airlifters. Rather than carrying all equipment on the soldier's body, arms and supplies could be carried in holders onboard the delivery vehicle.

4.4 Special Operations

A comment about delivery of Special Forces is in order. This subject has been studied many times, and Vertical Takeoff and Landing (VTOL) aircraft are being produced. We observe that while a few VTOL aircraft will, undoubtedly, be very useful, almost all missions can be completed with Short Takeoff and Landing (STOL) aircraft which have takeoff and landing distances of 100 meters or less. Engine power required is 50% less than for VTOL aircraft, and range and payload can be far higher for a given aircraft size and weight. A Short Takeoff and Vertical Landing (STOVL) aircraft can increase flexibility even more without large increases in weight or cost.

24. Mobility Volume

4.5 Aircraft Protection

Point-of-use delivery may place airlifters in locations where the threat level is higher than those now encountered. At least, though, the airlifter operates at high altitude, and the time available to respond to a threat will be longer than for an aircraft on approach or climbout at an airport. Airlifters should be equipped with a self protection suite which includes the following three capabilities (only the third requires development):

- ECM protection against radar seeking and RF command guided missiles.
- Fighter protection against other airborne threats, such as guns.
- Laser, High Power Microwave (HPM), or kinetic energy missile-killing systems against IR guided missiles, including focal plane arrays.[25]

5.0 Projection of Lethal and Sublethal Power

The Air Force understands well the issues associated with projecting power from airborne platforms. The subject of Precision Guided Munitions (PGMs) and their benefits needs no elaboration. We do, however, present ideas for making PGMs more effective. We will discuss power projection methods and devices which are different from those now in use. The Global Awareness and Dynamic Control capabilities will enable power projection capabilities not now possible in both existing and new platforms. Many of the fundamental tasks presented to the Air Force will not change much during the next decade. Added to the traditional air-to-air and air-to-ground missions, however, will be the countering and destroying of weapons of mass destruction and operations in urban areas. It is likely, too, that the availability of low cost SAM's will establish a premium for the their efficient destruction.

It is intellectually satisfying to discuss power projection in the abstract, and the technologist will frequently promote new and effective weapons without reference to their specific use. Such discussions are important, but they are usually too general, and they do not motivate the development of specific technologies and systems very well. We have discussed the control inputs to power projection in the sections on Global Awareness and on Dynamic Planning and Execution Control. These capabilities also provide target type and location. Here we will address the reasons and methods for projecting power. A more detailed discussion can be found in the Attack Panel Volume.[26]

The Air Force must project power globally. The methods by which this is done will vary depending on whether the nearest bases to the targets are within the range of fighter aircraft or not. In the worst case, only bases in the CONUS will be available. We expect situations to be more varied in the future than they were in the past. This statement is partly based on assessment of current world politics and partly on our ignorance of the future. In particular, we may execute more missions over "mixed" territory where the distinction between ally and enemy is blurred. We may also expect more operations in urban areas.

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25. SAB Study - *Aircraft Self Protection Against IR Seeking Missiles,* Phase II, December 1994
26. Attack Volume

5.1 Aircraft and Systems for Power Projection.

We explored the enhancement of existing aircraft and weapon systems during the study on *Life Extension and Mission Enhancement for Air Force Aircraft.*[27] The study identified avionics and training as the highest leverage technologies for improving the capabilities of the existing fleet. Those suggestions are appropriate for integrating the current fleet into the capabilities described in this report. Here we describe the justification of the Uninhabited Combat Air Vehicle (UCAV).

5.1.1 UCAV

An effective UCAV will be enabled in the next century as the result of the simultaneous optimization of information flow, aircraft performance, and mission effectiveness. The UCAV will not completely replace the inhabited aircraft for decades, if ever, but the presence, or absence, of a pilot is now a design trade that can be made in a logical way.

It is the improvements in sensors, processors, and information networks which make the UCAV possible. Information will increasingly be derived from sensors outside the air vehicle itself. Current concepts call for transmitting information derived from many sources over a satellite or ground-based link to the pilot of a high performance combat aircraft. The amount of information which can be injected into the cockpit is enormous. Discussion of pilot overload is common. More displays are needed in an already crowded cockpit, and more attention is demanded from an already overworked pilot. The question which must be asked, then, is whether it is more efficient to bring the pilot to the information rather than to bring the information to the pilot. The usual UAV issues, such as survivability, are secondary if performance is not compromised. When one considers the volume of information which will be necessary to conduct precision, high intensity operations of the future, it is possible that the most economical use of communication resources will be to transmit low bandwidth control, or control correction, information to the aircraft rather than to transmit mission information. The decision to use UCAVs will, of course, depend on the theater environment which has many variables such as the density of enemy jammers.

Information gathered from many sources, included from the UCAV, itself, will be brought to the Execution Control Center, which is located in the US, over high speed, massively redundant fiber and satellite communication routes. A permanent environmentally controlled installation will permit extensive use of state-of-the-art commercial equipment. Vehicle cost and weight will be reduced because of the absence of displays, pilot life support equipment, and manual controls. Volume, area, and weight of displays, processors, and controls in the Control Center can be large. Well rested mission specialists will be available to provide support for one or more UCAVs, and a cadre of expert, possibly civilian, maintenance technicians will also be available. The number of support personnel in the theater will be reduced, and it will not be necessary to transport a large number of shelters, workstations, and environmental control units. Extremely low observability of the UCAV will result in the reduction of standoff distance at the weapon release point and will, in turn, reduce weapon sensor, guidance, and propulsion costs.

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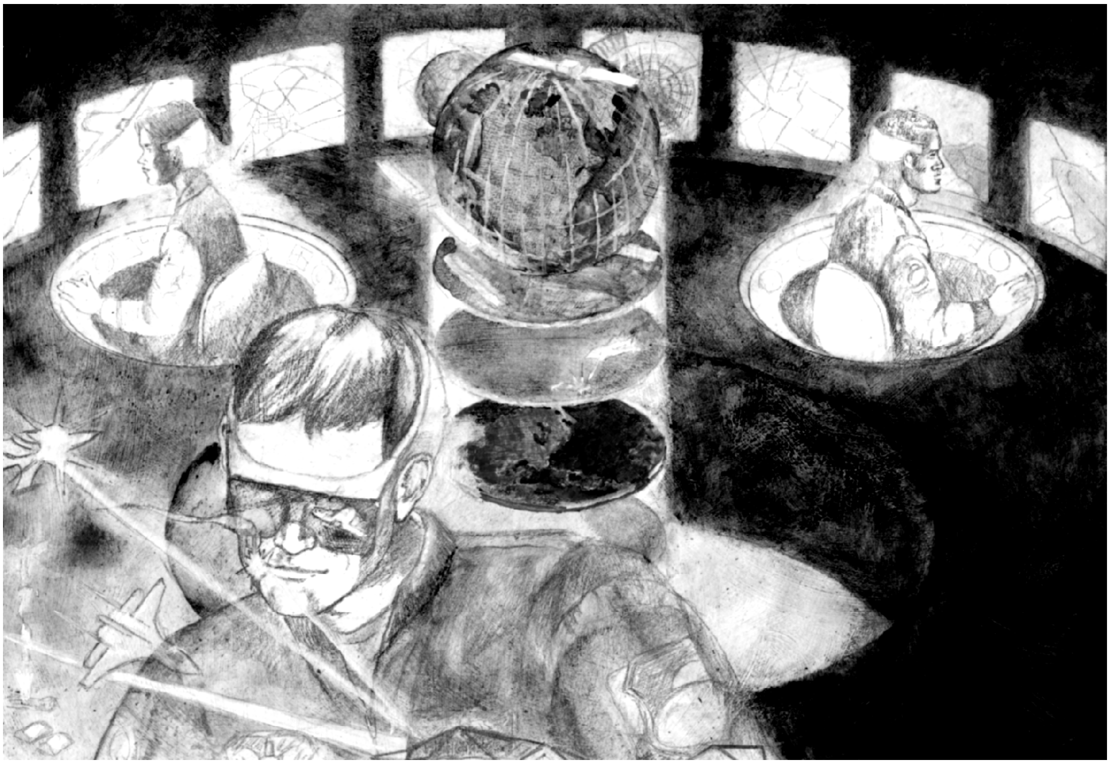
27. SAB Summer Study 1994, *Life Extension and Mission Enhancement for Air Force Aircraft,* August 1994



UCAV Control Center

Control technologies for UCAVs are not mature. The interaction between airframe and pilot will be cooperative and variable to a much greater extent than in existing aircraft. The pilot(s) will provide general direction in realtime when necessary. Control functions will be enabled by software agents transmitted from the Control Center. Agents will permit function changes such as from ground attack to air defense during a mission. Unplanned maneuvers can be generated in realtime.

UCAV survivability can be increased by increasing maneuverability beyond that which can be tolerated by a human pilot. Acceleration limits for inhabited aircraft are, typically, +9 g or 10 g and -3 g. A UCAV can be designed symmetrically to accelerate in any direction immediately. Anti-aircraft missiles are usually designed with a factor of three margin in lateral acceleration over that of the target aircraft, although a few missiles have acceleration capability as high as 80 g. A UCAV with a ±10 g capability could outfly many missiles, and an acceleration capability of ±20 g will make the UCAV superior to nearly all missiles.

Removal of the pilot from the aircraft also makes possible more options for signature suppression. Inhabited aircraft have limited options of shape and cross sectional area which limit the options for minimizing drag and radar cross section. Maneuvers and flight attitudes not appropriate for inhabited aircraft can also be executed to reduce the cross section presented to an adversary. The UCAV will also provide design flexibility for active stealth systems when they are developed.

The Air Force should pursue the design of a UCAV. It appears logical to begin with cruise missile parameters such as those of the Advanced Cruise Missile and then to increase capabilities by scaling. The inverse procedure of scaling down from an inhabited aircraft, say the F-22, may lead to higher cost and cross section. Operational concepts should be developed, and new weapon options should be pursued. Novel methods to optimize the interaction of remote pilots with a UCAV should be explored through simulation. Control and communication methods should be developed. The point to be made here is that the UCAV is a unique aircraft, and it should be designed as such.

5.2 Critical Tasks

There are a number of tasks which must be accomplished. Particular targets of importance are:

- Aircraft
- Fixed
- Mobile
- Chemical, biological, and nuclear weapons and production facilities
- Urban[28]
- Enemy directed energy weapons
- Short dwell targets
  - Theater ballistic missiles
  - Surface to air missiles
  - Vehicles - armored and unarmored
- Cruise missiles
- National forces
- Terrorist groups
- Concealed
- Personnel
- Protected command centers
- Information systems

We will not address all categories in this chapter, but we will discuss the ones which involve new technologies. It is frequently true that operational considerations dictate the technological philosophy applied to the development of a new weapon system. In the case of

28. Classified Volume - on file at the SAB Office

targeting in the Future Force described in Chapter I, the converse is true. Accuracy, reliability, and cost considerations dictate a discipline of delivering a weapon to a particular set of coordinates using GPS/Inertial guidance, if possible. We realize that it will not always be possible. There will be targets which demand specialized sensors or remote control. Of those two, automated remote control from a precision platform, such as a UCAV, is preferable. We encourage the weapon designer of the 21st century, though, to consider non-coordinate options as a last resort—not as a method of choice. Generic attack tasks for important targets are discussed in the following paragraphs.

5.2.1 Fixed Targets

We define fixed targets as those which remain nearly stationary long enough that they can be struck by a weapon which is directed to a particular set of coordinates. Many types will come to mind. Airbases, storage depots, command centers, and rail yards all fit the description. Not so obvious are parked or very slowly moving vehicles such as missile launchers, SAM, and artillery pieces. A “nearly stationary” target is one whose movement is less than the accuracy of the weapon during the weapon flight time. Targets may be fixed for minutes or permanently. In general, a fixed target is one that is detected by sensors on- or off-board the delivery platform, and the weapon is targeted by coordinates alone. The distinction is useful, because weapons which can be targeted by coordinates alone can have sensors and controls which are far simpler than those needed by weapons which attack moving targets, as mentioned above. In fact, if adequate precision can be obtained in platforms, release mechanisms, and weapon cases, it will be possible to achieve precision munition performance with no sensors onboard the weapon. There appears to be no fundamental physical reason that a weapon released from a high speed aircraft cannot be as accurate as a rifle bullet. Reentry vehicles delivered by Intercontinental Ballistic Missile (ICBM) are at least that accurate. Platforms must be low observable, fast, and designed around the weapons. We believe that the UCAV is the ideal platform for delivery of unguided weapons. Extensive, reusable, (and, therefore, affordable) sensor suites can be aboard the UCAV. A class of fixed targets which will be addressed separately is that of short dwell targets.[29]

Although all fixed targets can be addressed with common sensors, or no sensors, and delivery methods may be very much the same for all, the energy applied to the target may vary considerably with the target type. If sublethal response were in order, High Power RF (HPRF) weapons could be used against vehicles and electronic devices. The deployment of HPRF by cruise missile is discussed in the Munitions Panel Volume.[30] Flexibly fuzed munitions will be the weapon of choice against structures. Area coverage will continue to be provided by multiple small munitions, but we observe that multiple fixed targets do not, necessarily, demand multiple sensors onboard the weapon. However, autonomous precision micro munitions based on low cost electro optical systems may become inexpensive enough to alter the tempo of warfare dramatically. Interdiction will continue to be the most uncertain of operations in terms of weapon requirements for a particular mission, but technology can produce more flexible weapons to increase mission effectiveness.

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29. Sec. 5.2.6
30. Munitions Volume

5.2.2 Mobile Targets

Mobile targets deserve particular attention for many reasons. They offer opportunities for technology to increase the effectiveness of air to ground attack. It is more important, though, that a future target set may contain more mobile targets than fixed targets. Critical fixed targets can be nonexistent or prohibited by policy. We have endured both cases in the past. In fact, since World War II, the Gulf War was the only war where nearly all important targets could, in principle, be attacked. Fixed targets of the future may only be those associated with close air support and interdiction.

Mobile targets are special because of the variability of hardness as well as because of their motion. We possess specialized munitions which are nearly as varied as the weapon set, and which have special sensors, special explosive systems, special propulsion systems, and special delivery methods. It is the variability of weapons which makes planning for an interdiction mission much more difficult than planning for other missions. We may point proudly at a large variety of munitions which attack a large variety of targets, but we must remember that in interdiction the cycle time increases, and the sortie rate decreases, with an increasing number of weapon types. The absurd limit of type proliferation prohibits loading of weapons on aircraft until all targets for an interdiction mission are identified precisely. Effective use of camouflage and concealment measures by the enemy will complicate the process even more. Targets of opportunity could be restricted to those which fit the weapons already onboard the aircraft when the target is detected. The immediate solution for the commander, of course, will be to load aircraft with munitions which will destroy the most difficult targets that may be encountered during the mission. These are likely to be the heaviest or the most expensive munitions in the inventory. An alternate strategy is to load specific aircraft with specific weapons. Either strategy reduces overall sortie effectiveness.

Advances in sensor, fuzing, and control technologies offer a partial solution to the problem. Focal plane sensors and low mass, low volume processors can be developed to select the most vulnerable point on a given target, and precision controls can direct the munition to that point. One must think of accuracy in centimeters, not in meters, because advances in these areas are materializing at a rapid rate. Weapon effects can be varied by detonating the munition in various modes. For example, a shaped charge penetrator can be created for armored vehicles, and more uniform blast or fragmentation effects for softer targets can be produced by varying the detonation sequence in a single device.

Cost is a major factor in precision weapons, but commercial developments will reduce component cost. Further cost reductions can be attained by placing most of the processing and sensing functions on the delivery platform and communicating target information to the weapon.

It is often sufficient simply to stop moving targets. Unarmed vehicles can be left immovable. An immobile armed vehicle becomes a fixed target which can be destroyed with simple munitions. Of course, stopping and destroying an aircraft are equivalent processes. HPRF weapons can be effective against vehicle ignition systems and aircraft control systems.

5.2.3 Weapons of Mass Destruction

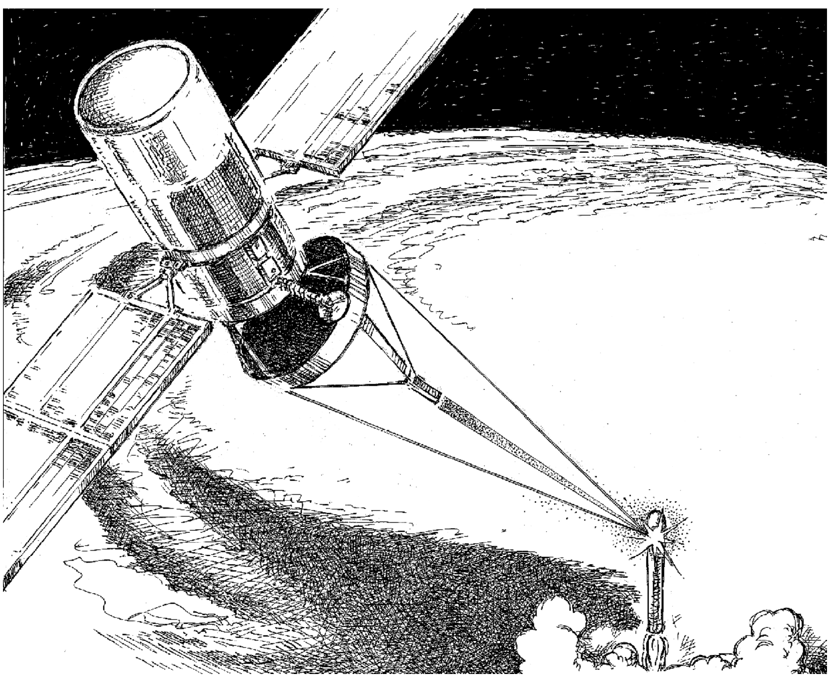
There are no weapons which address all threats. The danger of attacking weapons of mass destruction is in spreading toxic or biological active materials. Therefore, most solutions will immobilize, not destroy, these weapons. Destruction of production facilities will be deferred by isolating facilities and rendering them inaccessible or unusable. An entire stable of advanced precision and directed energy weaponry will be necessary.

5.2.4 Terrorists in Urban Areas

Terrorist operations are usually characterized by the proximity of noncombatants. Hostage situations are possible. These situations are treated at present by special teams using appropriate weapons. Air Force participation is limited to delivery of combat teams and supplies. In the future, however, the development of sublethal weapons deployed from aircraft and URAV sensors will increase Air Force responsibilities in this area. *A weapon which can have a very large impact on urban warfare and hostage situations is discussed in the classified section of the report.*

5.2.5 Directed Energy (DE) Weapons

We have identified directed energy weapons as coming of age. We cannot discount the possibility that an adversary will develop such weapons. It is well known that development of directed energy weapons was well supported in the Soviet Union. The technologies involved may be for sale in the future. Therefore, as we develop these weapons, we should define countermeasures.



Space Based Global Precision Optical Weapon Attack on Boosting Ballistic Missile

Development of hardening standards for probable enemy weapons is the first step. Seekers for lasers and HPRF can be developed. Ranges need only be consistent with the ranges of DE weapons. The sensing problem is not difficult, because of the high intensities involved.

5.2.6 Short Dwell Targets

We define short dwell targets as those that are vulnerable for a time short enough that their vulnerability is determined by the exposure time rather than by characteristics of an attacking weapon. Mobile missile launchers are an example. Launchers can be concealed, camouflaged, or protected by a structure until ready for use. After use they can be moved rapidly to a protected, or concealed, position. It is the protection of the target which distinguishes it from a mobile target.

Attack on short dwell targets is enabled by two factors - identification and weapon delivery. The Global Awareness system will detect and identify a target. If there is a URAV staring at the area of interest,[31] the Global Awareness system will deliver target coordinates to an accuracy of one meter or better, and the Dynamic Planning and Execution Control system can target a coordinate-seeking weapon in seconds. Detection by satellite constellation to an accuracy of 2-3 meters is adequate for the deployment of weapons having warheads of 50-100 kg. Targets such as Multiple Launch Rocket Systems (MLRS) and Transporter Erector Launchers (TEL) for theater ballistic missiles will be particularly vulnerable to this weapon system if weapon delivery times are short enough. If observation is by a URAV, an accuracy of 30 cm or less can be obtained, and warheads as small as 0.1-1 kg can be used. These weapons can be carried aboard the URAV. SIGINT detection by a distributed satellite constellation followed by coordinate transfer to a weapon will be extraordinarily effective against SAM sites and other facilities which radiate infrequently.

The best known short dwell target is the theater ballistic missile (TBM). The airborne laser (ABL) is an excellent first attempt to destroy TBM's in boost phase. The program will develop the user database for future applications of lasers as well. We encourage the development of the ABL and associated research to improve capability.[32] The ABL will require a high speed command and control system. Experience in the development of this system will provide a guide for addressing short dwell targets in general in the future.

Short dwell targets of importance are also high value targets. Therefore, a short dwell attack weapon can be useful even if the probability of destroying the target is low, and the cost is high. Attack at considerable distance is usually necessary. Warheads of 100 kg mass can be delivered by a 500 kg missile at a velocity of 2-3 km/s. A target having a 5 minute dwell and a 2 minute targeting time at a range of 400 km can be attacked. This appears to be a reasonable goal for a short dwell attack weapon which will be useful when used with URAV surveillance for the next decade and for a distributed satellite system the decade after that. Affordability is a significant issue. If coordinate targeting is used, a unit cost of $250K-$500K is possible. Other seekers and higher weapon velocities will cost more. Average weapon velocities as high as 4 km/s can be attained, but missile cost may be $1M.

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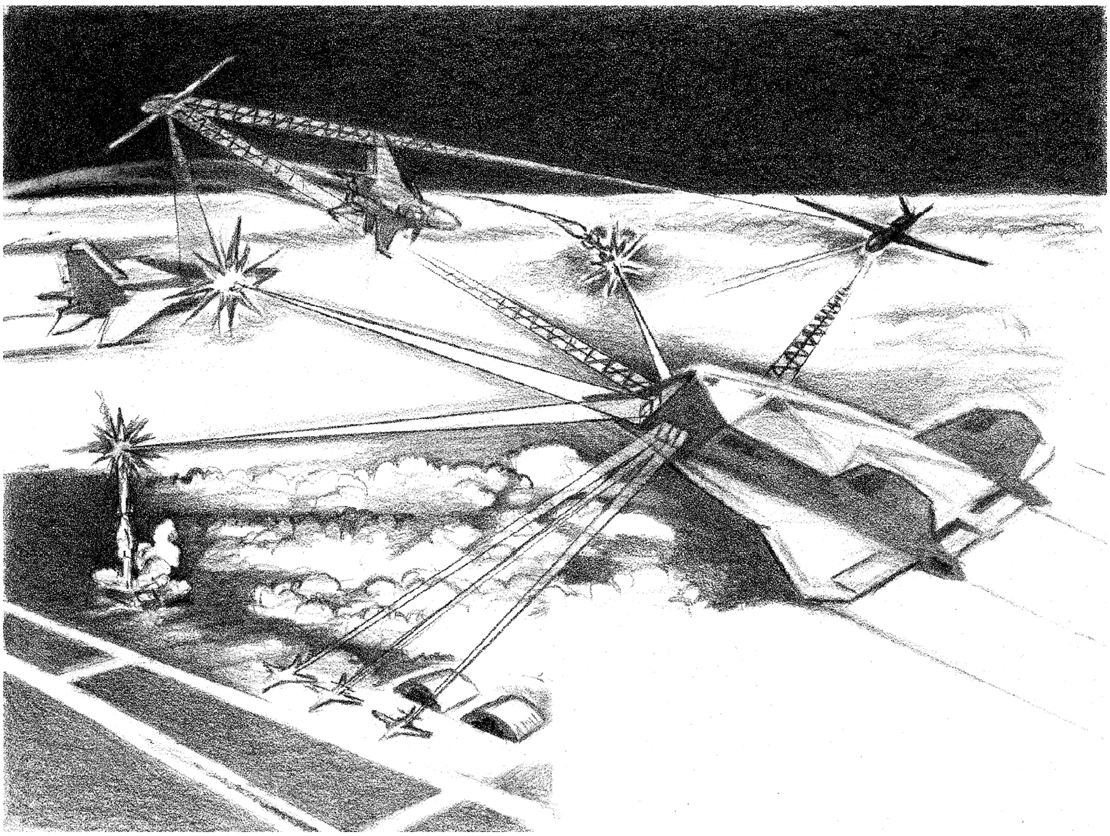
31. Sec. 2.3 and 2.4 of this chapter
32. Directed Energy Volume

The UCAV can be designed as a hypersonic weapon delivery platform. Reusable UCAVs which deliver unguided or coordinate guided weapons may be cost effective when compared to individual missile costs of $1M. For the UCAV, air breathing propulsion or a combination of rocket and air breathing propulsion may be the system of choice. Design and construction of a hypersonic aircraft at 4-5 km/s, Mach 12-15, will be complex and will require new airframe and propulsion technologies. Flight altitudes will range from 25-45 km (85,000-150,000 feet). A hypersonic UCAV will, undoubtedly, be far less expensive than a manned vehicle, and performance will be superior. For example, higher skin temperatures can be tolerated. The vehicle will transition from subsonic to supersonic to hypersonic flight as altitude increases and will transition back to lower speed and altitudes near the target. Velocity transition will obviate the need for a new class of weapons for hypersonic release.[33]



UCAV Fotofighter Attacking Air and Land Targets with High Power Laser Beams

5.2.7 Cruise Missiles

Large numbers of cruise missiles are extant worldwide. The success of the Tomahawk in the Gulf War demonstrated their efficacy to the entire world. We can expect sales and use of

33. Aircraft and Propulsion Volume

cruise missiles to increase during the next decade. Cruise missiles present special problems of detection and destruction. The missiles are small, and they present low radar cross sections. Missiles which fly at high altitude can be attacked as are conventional aircraft. Cruise missiles are slow, vulnerable, and maneuver little. They can be intercepted and destroyed by existing air-to-air missiles.

Low flying missiles are far more difficult to detect than their high flying analogs. The bistatic radar system described in Sec. 2.2 of this chapter is the best candidate for an affordable detection system with wide area coverage. Command guided missiles with IR sensors to provide terminal guidance can be developed. An airborne laser system can intercept and destroy low altitude cruise missiles at a range of a few 10's of kilometers. HPRF systems aboard large aircraft and ground based systems can be effective at similar distances.

5.2.8 Concealed and Camouflaged Targets

Detection is the primary issue associated with these targets. Detection probability will increase as sensor spectral range and number of viewing angles are increased. The Global Awareness system of Sec. 2.0 is well suited to the detection of concealed targets. The spectrum covers RF to optical wavelengths, and multiple viewing angles are provided by the distributed satellite and bistatic radar systems. Emissions are detected by the distributed satellite synthetic aperture signal locating system.[34]

5.2.9 Information Systems

Methods for attacking information systems are under development, and we believe that the technologies being pursued in many areas are appropriate. An important issue to be addressed is the integration of information system attack with the capabilities described in this Chapter. The computer oriented attack methods should be integrated with the Global Awareness and Dynamic Planning and Execution Control systems. For example, techniques developed for locating enemy information systems can be integrated with these systems to permit attack with explosive munitions. Location of threat information systems is also an integral part of Global Awareness. *The entire fabric of Information Warfare should be joined to the fabric of more conventional warfare.*

6.0 Space Operations

Space operations will become increasingly important to the successful completion of most missions in the 21st century.[35] The essential role of Space in Global Awareness and Dynamic Planning and Execution Control was discussed, and, in particular, the value of distributed satellites was addressed. The interaction between military and commercial space applications has not begun to evolve. It is time, now, for the Air Force to define its relationship with commercial and international space organizations. Commercial organizations have used satellites for communications for years. Geosynchronous satellites form an important part of the worldwide communications system, particularly for the relay of one-way broadcasts. For two way communications, fiber is rapidly becoming the medium of choice. Commercial applications

34. Sensors Volume
35. Space Applications Volume

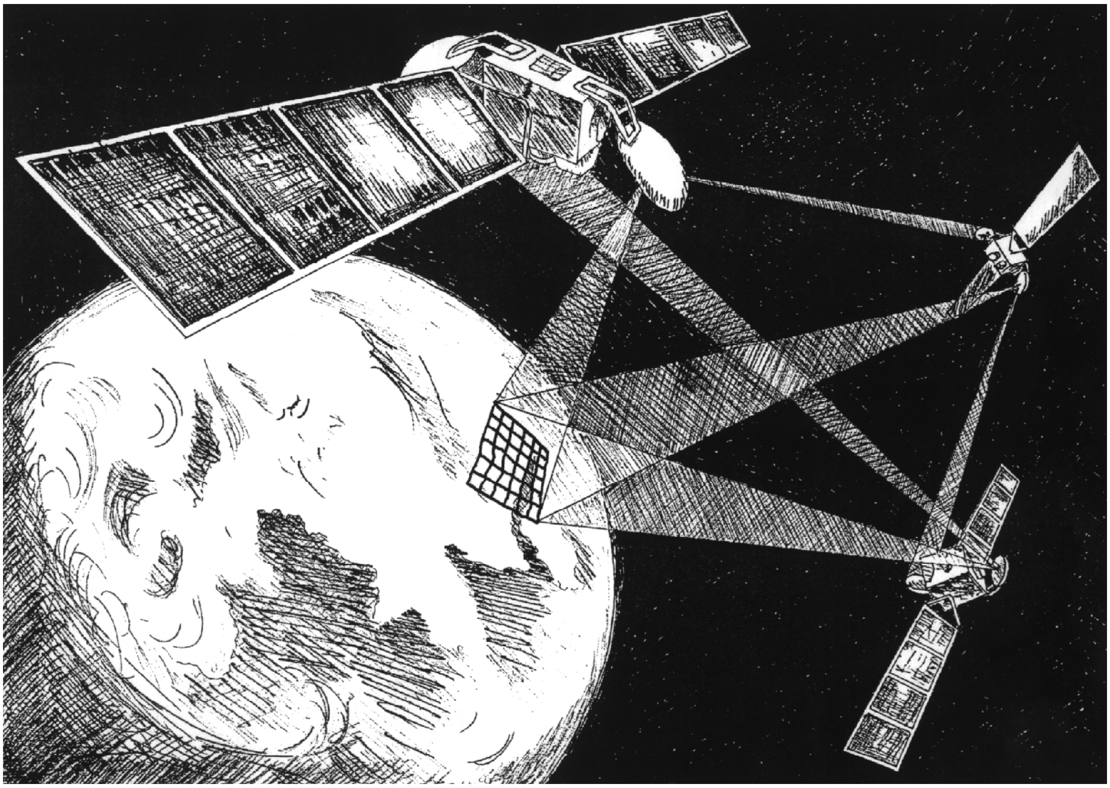
during the next decade will include distributed constellations for cellular communications of voice and data from low power ground transmitters and high resolution imaging systems. The direct use of these systems for military purposes will be cost effective. We must realize, however, that commercial systems will not provide a one-for-one replacement for analogous military systems. The way in which the systems are tasked and the way in which their information is used will require changes in requirements for communication and imaging products.

6.1 Distributed Satellites

Affordable use of distributed satellite constellations will require discipline in the design and launch of space vehicles. The launch of a satellite is now an unusual event. Each launch resembles a technology demonstration. It is common for a satellite to contain many unrelated devices solely because volume or launch mass is available. The result is high cost and mass. If lightweight distributed systems are to be of use, this practice must be controlled. Single, or dual purpose satellites must be the rule rather than the exception. If two or more systems coexist on a single satellite, their functions should be complementary. Pressure to include unrelated devices results from excessive cycle time. Cost is also proportional to the time required to design and build a satellite. *Time from design to launch should be reduced substantially. A goal of two years is reasonable.*

Small distributed satellite systems can provide the warfighter with relevant, timely information at a cost below that of large systems. Humans tend to be visually oriented, and we have depended on images to provide us much of what we know about the battlefield. During the past decade, or so, we have learned that imaging outside the visible band, particularly in the infrared, can give us important information beyond that obtained from a visible image. More recently, Synthetic Aperture Radar (SAR) images have begun to contribute important data. The relaxing of image resolution requirements results in smaller sensor packages which can be flown on small, less expensive satellites. The addition of hyperspectral capabilities does not add weight or volume as rapidly as does image resolution, and a hyperspectral sensor with a spatial resolution of 10 m probably optimizes cost and coverage. Systems can be inexpensive enough that advances in processor and sensor technologies can be incorporated in a timely way. Technologies are improving significantly on a timescale of two years—a time consistent with commercial satellite system development times. *A two year period from the beginning of design to launch should be a firm goal. Opportunities for leveraging commercial technologies are many in this area.*

The ultimate utility of a distributed satellite system, a distributed URAV system or a distributed information system of any type derives from cooperative action. Multiple systems which improve performance linearly with the number of objects deployed are not properly classified as distributed systems. True distributed systems increase performance at a rate which is faster than linear with the number of systems deployed. In some cases, for example, a single satellite can perform processing tasks for a large number of special purpose satellites if an onboard communication link is smaller or lighter than a dedicated processor. A central processor will reduce the processing requirements of individual satellites in the constellation. Processors usually are sized for peak rather than average loads, and a central processor can be operated more efficiently than a large number of small ones. In addition to central processing, cooperative detection is possible. For example, several satellites, each of which has a view of a particular region of interest could measure the phase of a transmitter simultaneously to determine the phase of an emitter. The long baseline will make precise location of the emitter possible.[36] We have discussed the use of commercial imaging for mapping[37] and the use of commercial constellations for providing communication services for onboard military hyperspectral systems.[38] Those discussions will not be repeated here. Rather, we will concentrate on access to space, control of space, and the projection of power from and to space.



Distributed Satellites Cooperatively Scanning a Target Area

6.2 Access to Space

The use of space has been limited by the high cost of placing satellites in orbit. The cost of mass on orbit is approximately $20,000 per kilogram. Many studies of space launch have searched for ways of reducing cost, but none have proposed a definite way of reducing cost substantially. We have no specific solutions, but we will suggest long term research which may help.

The computational design of molecules is becoming possible as the result of increasing computation power. *The Air Force should substantially support research into the*

36. Sec. 2.1 of this chapter
37. Sec. 2.0 of this chapter
38. Sec. 2.5 of this chapter

computational design of energetic materials.[39] Both explosives and rocket fuels should be included. It may be possible to develop fuels which have higher specific impulse, Isp, than those available now, but the use of these materials is not a simple matter. Higher Isp is related to higher exhaust velocity which, in turn, is related to higher combustion temperatures. Thus, an increase in Isp can require combustion chamber materials which will operate at temperatures and pressures higher than do those currently available. We should, therefore, search for Isp increases which are not achieved by increasing combustion temperature.

Of course, lighter satellites can reduce the cost of launch for a particular function even though the cost per pound is not reduced. Mass reduction can be achieved through the use of lower density, stronger materials and through the use of stronger lightweight structures. In the longterm biological structures may be useful.[40]

Reusable launch vehicles have been proposed as a way of reducing launch cost. It appears, though, that the cost of vehicle preparation dominates the cost of vehicles. Launches are prepared and monitored by a “cast of thousands” operating a vast array of equipment. Reusable vehicles amortize their cost over a large number of launches, but unless they have greatly reduced logistics tails, little reduction of cost can be expected. If a reusable vehicle is to be cost effective, it must need little refurbishing and testing between launches. The goal should be to achieve “airplane-like” operation of space launch vehicles. Today, space launch is more akin to a science experiment than to a routine takeoff. This situation must be changed if cost reductions are to be achieved. Utilization of the rapid increase in capability of information systems should reduce the number of people required to launch a space vehicle.

Automated launch control and mission monitoring systems should be designed to reduce the number of people involved in launch and mission control by at least a factor of ten.

Orbit transfer from low earth orbit to geosynchronous orbit can be addressed by electric propulsion. Research in this area should be strengthened.

Although military launch capability must be maintained as a vital part of national security readiness, *our goal should be to launch most military satellites aboard commercial launch vehicles*. The use of commercial capability will necessitate the design of military satellites which are compatible with the available launchers. The distributed constellations do just that. The norm should be satellites of volume and mass similar to those of Iridium or Teledesic. It will require discipline to produce satellites that have only one function, but cost, functionality, and reliability will demand single, or perhaps dual function satellites. Reliability is now a problem with commercial launch vehicles, but this situation will improve. We should be prepared for launch failure probabilities of 10-15 percent in the initial years of deployment of constellations. Reduced reliability dictates lower cost satellites, and smaller, distributed systems are, again, favored. Miniaturization, reduced design and planning time, and single or, at most, dual purpose satellites will make space systems affordable.

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39. Space Technology Volume
40. Materials Volume